



Transportation Synthesis Report

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Optimal Joint Spacing for Concrete Pavement

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Transportation Synthesis Reports (TSRs) are brief summaries of currently available information on topics of interest to WisDOT technical staff in highway development, construction and operations. Online and print sources include NCHRP and other TRB programs, AASHTO, the research and practices of other state DOTs, and related academic and industry research.

REQUEST FOR REPORT

Joint spacing on concrete pavements has followed various trends over the years and often becomes a matter of convention, with states following specifications set in previous years. The RD&T Program was asked to identify recent research on optimal joint spacing.

SUMMARY

Most research on spacing concerns load transfer and joint sealing, and a large body of research on overlays entails joint spacing directives. Yet there is some work on the relationship between joint spacing and concrete thickness as well as cracking. The FHWA offers data, as well as spacing calculation tools in design software, through its Long Term Pavement Performance program. Industry groups like the American Concrete Institute and American Highway Technology have recently issued guidelines for durable paving that include joint spacing design specifications. In addition to the sparse national and international work on joint spacing, several projects are currently in progress that may provide clearer data on the relationship of joint spacing to pavement performance.

RECENT RESEARCH AND GUIDELINES

Long Term Pavement Performance (LTPP) Rigid Pavement Design Software See product brief at <http://www.tfhr.gov/pavement/ltp/pdf/99129.pdf> and article in September 1999 issue of Focus at <http://www.tfhr.gov/focus/sept99/portland.htm>. The Long-Term Pavement Performance project offers this software incorporating the latest in NCHRP research and AASHTO regulations. The software considers various input factors before issuing data on optimal joint spacing, base type, sub-grade support, and estimations of the likelihood of cracking. It also offers calculations of optimal joint spacing for specific project characteristics. Users enter a proposed joint spacing dimension – such as 15.0 feet – as a direct input and receive tables and projections of concrete performance based on the joint spacing and other input requested. The software can be ordered at <http://www.tfhr.gov/pavement/ltp/rigid.htm>. This same Web page offers slide presentations and other information on the software.

American Concrete Institute. “Designing Concrete Pavements for Streets and Local Roads,” Ward Malisch, *Better Roads*, Oct. 2002, <http://www.betterroads.com/articles/oct02d.htm>. This article summarizes the work of an American Concrete Institute study, ACI 325.12R-02, *Guide for Design of Jointed Concrete Pavements for Streets and Local Roads*. The Guide recommends “close” joint spacing, and offers various tools for calculating the best spacing strategy for the anticipated loads and slab thickness of roads; specific figures from the Guide were not offered in the above article. The ACI guide may be ordered through the ACI site bookstore, <http://www.concrete.org/BOOKSTORE/bkstr.htm> or from the Wisconsin Concrete Pavement Association.

American Highway Technology. “Technical Brief on Joint Spacing for JPCP,”

<http://www.americanhighwaytechnology.com/jointspacing.html>. This industry study of pavement joint spacing and its relation to pavement thickness offers detailed tables on spacing in relation to thickness and freeze-thaw characteristics, and a cost analysis of spacing practices. (Unfortunately, the graphics on the Web page tend to load slowly and, sometimes, incompletely. See an abstract version of the brief in the May 2000 issue of AHT’s Mileposts newsletter, page 2, at <http://www.americanhighwaytechnology.com/pdfs/milepost.pdf>.)

- Affirms American Concrete Pavement Association guidelines of 12- to 20-foot spacing of jointed plain concrete pavement, suggests FHWA’s design maximum of 15 feet may be too conservative for every paving situation.
- Stiff bases and sub-grades require shorter spacing than soft bases.
- Skewed joints should not be used if dowels installed, and non-uniform spacing should operate with structural design principles based upon the maximum joint space employed.
- Cost-benefit is a critical parameter to be considered with spacing and slab thickness; the thicker the slab, the wider the spacing, as a general rule.
- A slide show on the American Highway Technology Web site by ERES Consultants gives a quick version of the cost implications and relationships of varying joint spacing and pavement thickness – <http://www.americanhighwaytechnology.com/loadtransfer/loadtransfer.html>.

National Ready Mixed Concrete Association. “What, Why and How? Curling of Concrete Slabs,” *Concrete in Practice*, No. 19, 1990; <http://www.nrmca.org/engineering/cip/CIP%2019p.pdf>. When curling seems likely, the NRMCA recommends joint spacing not exceeding 24 times the thickness of the concrete slab.

DOMESTIC RESEARCH

“Preliminary Evaluation and Analysis of LTPP Faulting Data – Final Report,” O. Selezneva, J. Jiang, and S.D. Tayabji, Sept. 2000, FHWA;

<http://199.79.179.82/sundev/detail.cfm?ANNUMBER=00800165&STARTROW=11&CFID=204611&CFTOKEN=34350443> (abstract). In doweled jointed pavements, joint spacing had little impact on cracking, as dowel presence proves more important to preventing damage than other design parameters. In non-doweled jointed plain concrete, however, faulting was best prevented through adjustments to design parameters used in doweled joint concrete, including shortening of joint spacing.

“Benefits and Costs of Jointed Plain Concrete Pavement Design Features,” N.G. Gharaibeh and M.I. Darter, *Transportation Research Record*, No. 1778, Design and Rehabilitation of Pavements 2001; <http://199.79.179.82/sundev/detail.cfm?ANNUMBER=00824531&STARTROW=11&CFID=204611&CFTOKEN=34350443> (abstract). Researchers present a methodology for evaluating costs and benefits of various jointed plain concrete pavement design features, including joint spacing, but do not pursue optimal design suggestions. Life-cycle costs are computed relative to a reference design, based on predictions of distresses and smoothness and on a maintenance and rehabilitation policy.

“Performance of Transverse Cracking in Jointed Concrete Pavements,” M.A. Frabizzio, N.J. Buch, *Journal of Performance of Constructed Facilities*, Vol. 13, Issue 4, Nov. 1999, pp. 172-180; <http://199.79.179.82/sundev/detail.cfm?ANNUMBER=00779586&STARTROW=11&CFID=204611&CFTOKEN=34350443> (abstract). This ASCE paper focuses on evaluation methodologies for analyzing cracked pavement, but finds joint spacing to be a significant design factor affecting transverse cracking.

- 49 jointed concrete pavement sites in southern Michigan were selected; sections were 25 meters (82 feet) to 65 meters (213 feet) in length, with two to eight slabs in each, 3 to 29 years old, with slab thicknesses of 178 mm (7 inches) to 305 mm (12 inches).
- When spacing was increased from 4.9 meters (16 feet) to 8.2 meters (27 feet), number of cracks in surface doubled; increase to 21.6 meters (71 feet) increased cracks fourfold. Investigators concluded longer spacing leads to more transverse cracks per slab.

“Developing New Design Details for Urban PCC Pavements,”

<http://www4.nationalacademies.org/trb/scor/states.nsf/a34ffb91753b26c485256ada0048be6e/a7d9e5100be96ebb85256896005837f5?OpenDocument>. This NYDOT study is featured on AASHTO’s Research Advisory Committee Web site as an example of “high value state DOT research.” The study employs finite-element analyses of urban pavement stress to conclude that slabs containing manholes are best fixed at a length of 3.5 meters (11.5 feet), and adjacent slabs can vary in length from 3.5 to 5.5 meters (18 feet).

TRB 2003 Annual Meeting Presentation. “3D Finite Element Analysis of Jointed Plain Concrete Pavement with EverFE2.2,” William G. Davids, Zongmu Wang, George Turkiyyah, Joe P. Mahoney, David Bush; see TRB 82nd Annual Meeting Compendium of Papers CD-ROM. Based on a computer model of limited scope, investigators determine that shifts in joint location and spacing impact dowel bar shear more than load transfer (7-9). Spacing recommendations are not included.

TRB 2003 Annual Meeting Presentation. “Evaluation of Load Transfer Efficiency for SMP Sections in LTPP Database”; see TRB 82nd Annual Meeting Compendium of Papers CD-ROM. Focused on load transfer efficiency with respect to dowel bars, this study determines that load transfer efficiency diminishes with respect to joint spacing increases from 0.7 percent LTE at 3.8 meters (12.5 feet), to about 0.575 percent at 5.35 meters (17.5 feet) for the initial installation. See p. 18, Figure 5, “Effect of Joint Spacing on LTE.”

INTERNATIONAL GUIDELINES AND RESEARCH

University of Durham. “Pavement Design – Thickness Design,”

<http://www.dur.ac.uk/~des0www4/cal/roads/pavdes/thicknes.html>. The School of Engineering at University of Durham produced guidelines for rigid pavement design, with specifications regarding several factors, including joint spacing. Links to related research are provided, but the basic recommendations are:

- For un-reinforced concrete, slabs thicker than 230mm (9 inches) require contraction joints every 5 meters (16.5 feet); slabs under 230mm thick require joints every 4 meters (13 feet). Expansion joints should replace every third contraction joint.
- For reinforced jointed concrete, contraction joints are required every 25 meters (82 feet), though this may vary with volume of reinforcing material, per a design chart; every third joint should be an expansion joint.

International Conference on Highway Pavement Data, Analysis and Mechanistic Design Applications.

“Evaluation of Joint and Crack Load Transfer for LTPP Pavement Sections,” Lev Khazanovich and Alex Gotlif, paper number 0340; <http://webce.ent.ohiou.edu/orite/Conference/0340.htm>. A paper to be presented at this Columbus, Ohio conference in September 2003 will evaluate various design characteristics as they impact LTE. The abstract states that “Poor correlation was found between LTE and design parameters such as portland cement concrete (PCC) thickness, PCC strength, design steel content, joint spacing, and joint orientation.”

RESEARCH IN PROGRESS

The following research is in progress.

“Cost Effective Concrete Pavement Cross-Sections,” <http://rip.trb.org/browse/dproject.asp?n=2005> (abstract). This seven-year study for WisDOT by Marquette University began in June 1997 to investigate the performance of jointed pavements employing various load transfer mechanisms including variable joint spacing.

Concrete Pavement Technology Program. “Smoothness Criteria for Concrete Pavements,” Task 16(01). <http://www.fhwa.dot.gov/pavement/cptp17.htm>. A 30-month, \$500,000 study scheduled to begin in March 2003 investigating construction characteristics of smooth pavement, including joint spacing.

“Concrete Pavement Load Transfer Study,” <http://rip.trb.org/browse/dproject.asp?n=2385> (abstract). Joint spacing and other factors are being considered on Manitoba pavements in a 20-year study. Four test cells were constructed in 1992, and initial testing of load transfer efficiency was conducted in 1993 and 1994.

“Evaluation of Narrow Transverse Contraction Joints in Concrete Pavements,”

<http://rip.trb.org/browse/dproject.asp?n=7306> (abstract). A five-year Louisiana DOT inquiry, this study began in July 2000 to look in particular at properties and designs that encourage damage at or near joint positions, and considers sealants and maintenance of joints.